Newton's 2nd Law

2004	**C5.** An unladen helicopter of mass M kilograms can hover at a constant height above the ground when the engine exerts a lift force of P newtons. The helicopter is loaded with cargo which increases its mass by 1%. When airborne, the engine now exerts a lift force 5% greater than P to accelerate the helicopter vertically upwards. Calculate this vertical acceleration.	**5**
2009	**A7.** A block is released from rest at the top of a smooth plane which is inclined at angle θ to the horizontal. Show that the time, in seconds, taken for the block to reach the bottom of the plane is given by $$\sqrt{\frac{2h}{g\sin^2\theta}}$$ where h metres is the vertical distance between the top and the bottom of the plane.	**4**

Newton's 2nd Law with Friction

2004	**C4.** A ramp consists of a rough plane inclined at angle θ to the horizontal, where $\tan\theta = \frac{5}{12}$. A box of mass m kg is given a push up the line of greatest slope of the ramp, which gives the box an initial speed of $\sqrt{gL}\ \text{m s}^{-1}$, where L metres is the distance travelled before the box comes to rest. Calculate the value of the coefficient of friction between the box and the surface of the ramp.	**7**
2005 SP	**2.** A block of mass m kilograms is projected with speed $v\ \text{m s}^{-1}$ up a line of greatest slope of a rough plane inclined at an angle α to the horizontal. The coefficient of friction between the block and the surface of the plane is μ. The block travels a distance s metres up the plane before coming to rest. Find an expression for s in terms of v, α, μ and g, where g is the magnitude of the acceleration due to gravity.	**5**
2013	**A5.** A piano of mass 160 kilograms is resting on a rough plane inclined at an angle $\theta°$ to the horizontal, where $\tan\theta° = \frac{7}{24}$. When a removal man applies a horizontal force of 850 newtons, the piano is just on the point of moving up the plane. Find the value of the coefficient of friction between the piano and the surface of the plane.	**4**
	When the removal man increases the horizontal force to 1000 newtons, the piano begins to accelerate up the plane, along the line of greatest slope. How far does the piano travel in 3 seconds?	**2**
2014	**A5.** A body of mass M kg is moving upwards on a rough plane inclined at an angle $\theta°$ to the horizontal, where $\tan\theta = \frac{3}{4}$. As it passes through point A it has a speed of $u\ \text{m s}^{-1}$. It momentarily comes to rest at B and subsequently passes through a point C when moving down the slope with speed $2u\ \text{m s}^{-1}$. Given that the coefficient of friction between the mass and the slope is $\frac{1}{4}$, show that $AC = \frac{35u^2}{8g}$.	**6**

2017

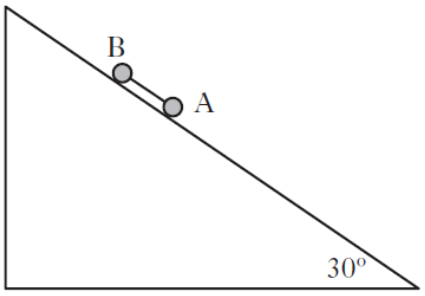
1. A skier starts from rest and skis straight down a slope inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{4}$. The coefficient of friction between the skis and the snow is 0·125.

Find the speed of the skier after she has travelled 75 metres. **4**

2015

A9. Two particles A and B of mass 30 grams and 20 grams respectively are held on an inclined plane.

A is below B and 2 metres from the bottom of the slope.



The particles are joined by a taut, light inextensible string of length 25 cm which is parallel to the line of greatest slope of the plane.

The plane is inclined at 30° to the horizontal. Contact between particle A and the plane is smooth while the coefficient of friction between B and the plane is 0·5. The particles are released from rest and move down the slope.

(*a*) (i) Find the tension in the string and the acceleration of the particles. **4**

(ii) Calculate the speed of B at the instant when it reaches the original position of A. **2**

When B reaches the original position of A the string snaps and the two particles travel independently down the slope.

(*b*) Calculate the time interval between A and B reaching the bottom of the slope. **4**

Work/Energy Principle

2007

A7. At a building site, bricks of mass 2 kg slide down a straight chute into a container. The chute is rough and inclined at 30° to the horizontal. The distance travelled down the chute by each brick is 10 metres. A brick is released from rest at the top of the chute. When the brick reaches the bottom of the chute its speed is 4 m s^{-1}.

Calculate the coefficient of friction between the brick and the chute. **6**

2010

A3. A sledge is released from rest at the top of a ski run which is to be modelled as a rough plane inclined at angle θ to the horizontal. The coefficient of friction between the sledge and ski run surface is μ.

Show that the distance, s metres, travelled down the plane by the sledge to achieve a speed of V m s^{-1} is given by

$$s = \frac{V^2}{2g(\sin\theta - \mu\cos\theta)}.$$ **4**

2012

A5. As a train leaves a station, it climbs a hill inclined at an angle θ to the horizontal where $\sin\theta = 0{\cdot}1$. The top of the hill is 100 metres above the horizontal level of the bottom of the hill.

The train's engine exerts a constant force of 120 kN and the coefficient of friction between the train and the tracks is 0·2.

The speed of the train at the bottom of the hill is 4 m s^{-1}. Given that at the top of the hill the speed of the train has increased to 10 m s^{-1}, calculate the mass of the train. **6**

2017

17. A body of mass 12 kg is moving down a rough plane inclined at an angle θ to the horizontal, where $\sin\theta = \frac{3}{4}$. As it passes through a point A it has a speed of 5 m s^{-1}.

(a) At a point B further down the slope its speed is 10 m s^{-1}.

Show that the distance AB is $\frac{150}{(3-\sqrt{7}\mu)g}$ metres, where μ is the coefficient of friction between the body and the plane. **5**

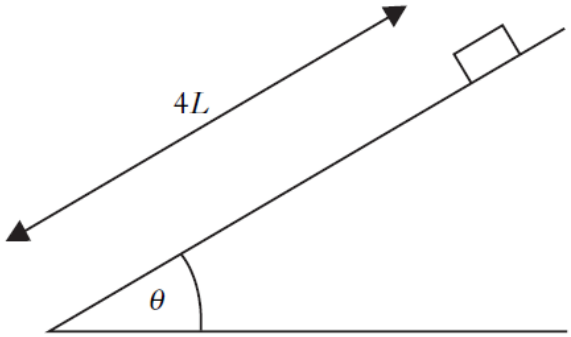
On reaching a speed of 10 m s^{-1} a horizontal force of 260 N is applied to the body. This brings the body to rest in a distance half that of distance AB.

(b) Calculate the value of the coefficient of friction.

Give your answer to **two significant figures**. **6**

2011

A8. A small box accelerates from rest down a rough plane inclined at an angle θ to the horizontal. After travelling a distance $4L$ metres, the box reaches the bottom of the plane with speed U metres per second. The coefficient of friction between the box and the inclined plane is μ.



Show that

$$\frac{U^2}{gL} = 8(\sin\theta - \mu\cos\theta).$$ **3**

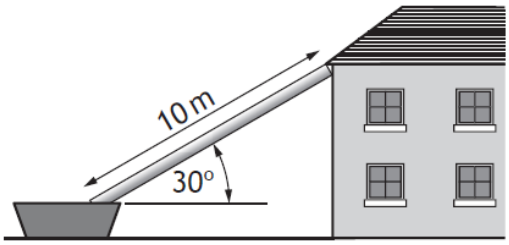
The box is now projected up the same inclined plane with initial speed U metres per second, coming to rest instantaneously after travelling $3L$ metres. Show that

$$\mu = \frac{1}{7}\tan\theta.$$ **5**

When $\tan\theta = \frac{3}{4}$, find an expression for L in terms of U and g. **2**

2016 SP

9. A house is being re-roofed. The old tiles slide down a rough plastic chute into a skip at the side of the house. The chute is 10 metres long and inclined at an angle of 30° to the horizontal as shown.



A tile of mass m kg is given an initial speed of $2\,\text{m s}^{-1}$ at the top of the chute. The coefficient of friction between the tile and the chute is $\frac{1}{2\sqrt{3}}$.

Show that the speed of the tile at the bottom of the chute is $\sqrt{53}\,\text{m s}^{-1}$. **5**